Physical Constraints From Broadband Afterglow Fits: GRB000926 as an Example

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Abstract. We develop a model to fit the broadband afterglows of GRBs from the intrinsic parameters of the fireball's synchrotron emission, and apply it to a few well-studied events, with the goal of constraining the intrinsic variability of GRB parameters. We give an example here of fitting to the recent bright event GRB000926.

1   Introduction

The single successful model of GRB emission to date has been the fireball model. A small amount of matter is accelerated to a large Lorentz factor Γ. Shock expansion produces synchrotron emission of radiation with a well-defined spectrum. The spectral breaks ν_{break} are functions of fireball parameters and depend on the hydrodynamics of the fireball's evolution. The hydrodynamics are strongly affected by the environment and geometry of the fireball, thus the afterglow's broadband lightcurves can in principle constrain fundamental parameters of the burst. For example, collimation of the ejecta produces an achromatic break, but the evolution of ν_{break} past observed frequencies does not.
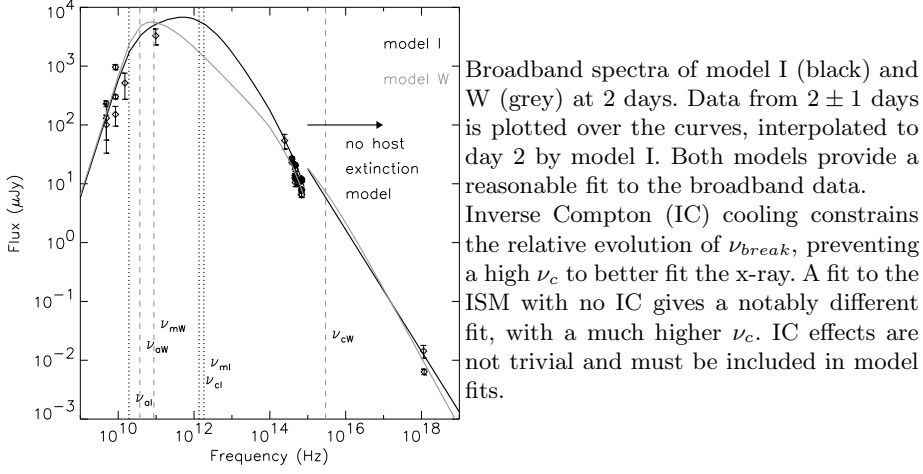
We consider two possible density profiles for the burst environment, r^0 as in the interstellar medium (ISM) and r^{-2} as from a constant stellar wind (WIND).

We calculate the synchrotron flux as a function of t,ν from the luminosity distance and redshift, and a set of fundamental parameters: isotropic-equivalent energy E, electron powerlaw index p, electron and magnetic energy fractions, ε_e and ε_B, as well as the circumburst density: a constant n in the ISM case or A ($\rho = Ar^{-2}$) in the WIND case. The equations are based on Sari et al [11] and Granot et al [3], [4] for the ISM model and Chevalier & Li [1] for the WIND model. Collimation effects on the evolution are based upon Sari et al [10]. We include the effects of inverse Compton scattering based upon Sari & Esin [9]. Host extinction is parametrized by A_V according to the prescription of Reichart [8].

This calculated flux is compared to observations corrected for Galactic extinction and host flux, and a Powell gradient search optimizes the model parameters.

2   GRB000926: Preliminary Results

The IPN detected this event on 2000 September 26.993 and rapidly disseminated its postion, leading to observations by many. We use the optical observations at ≤ 1 day post-burst by Hjorth et al [5] and Fynbo et al [2], along with the data presented in Price et al [7], with its calibration and host flux subtraction, as well as the x-ray data of Piro & Antonelli [6]. We allow a systematic calibration uncertainty of 4%, account for interstellar scintillations in the radio based on Walker [12], and calculate the best-fit ISM model (I) and WIND model (W).


Broadband spectra of model I (black) and W (grey) at 2 days. Data from 2 ± 1 days is plotted over the curves, interpolated to day 2 by model I. Both models provide a reasonable fit to the broadband data. Inverse Compton (IC) cooling constrains the relative evolution of ν_{break}, preventing a high ν_c to better fit the x-ray. A fit to the ISM with no IC gives a notably different fit, with a much higher ν_c. IC effects are not trivial and must be included in model fits.

Fig. 1.

Table 1. Model Parameters

	I	W	units		I	W	units
E	1.1	39	10^{53}erg	p	2.1	2.2	
n	0.62		cm^{-3}	A		1.5	$5 \times 10^{11} gcm^{-2}$
ε_e	0.27	0.012		ε_B	0.95	0.0025	
θ	0.083	0.044	rad	t_{jet}	1.2	1.8	day
A_V	0.2	0.3	mag				

   The fit to model I, including radio scintillation effects, gives a total χ^2 of 197 for 80 degrees of freedom. Model W has $\chi^2 = 171$ for 80 d.o.f.. Both models assume an LMC-like host extinction curve, though an SMC-like curve gave scant difference in the results.

   Models I and W both give a reasonable description of the data. Model W gives a better optical fit, but does not seem to fit the late-time radio data. Very late radio data may provide the best discriminant between the ISM and WIND.
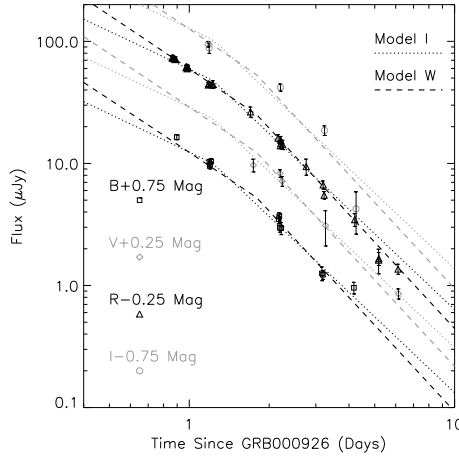
Fig. 2. GRB000926 optical lightcurves. Both I and W models fit reasonably well, though the R band is better fit by W, with its later jet break and steeper slope.
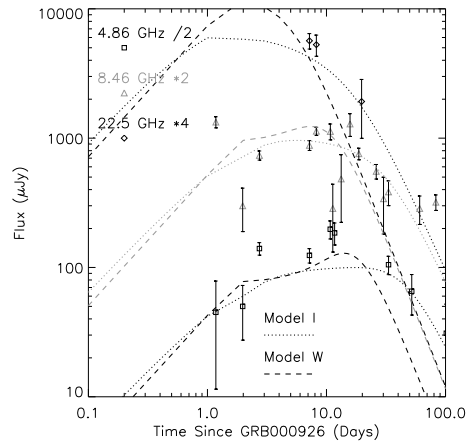
Fig. 3. GRB000926 Radio lightcurves. At 22.5 GHz, early observations could distinguish the models. At lower ν, I and W are distinguishable at late times, and I appears to fit better after about a month.

3 Conclusion

ISM and WIND models fit the afterglow of GRB000926, with non-negligeable Inverse Compton effects. The WIND underpredicts the late 8.46 GHz data, whereas the ISM model is a far better fit to the late radio observations, providing some evidence that this burst occured in a medium of constant density.

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